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The Composition and Properties of the Tailings of Quartzite Enrichment of "Gora Karaul'naya" Deposit

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Abstract

The JSC "DINUR" use enriched quartzite from the "Gora Karaul'naya" deposit in the production of dinas refractories. The tailings of quartzite enrichment are stored in the dump, not used, and thereby pollute the environment. Chemical, mineral and grain composition, physical, mechanical and technological properties of samples of quartzite tailings of the current output and selected from the dump are determined in this study. The tailings of current output contain less oxides of aluminum, iron and calcium and alkalis compared to the dump tailings. Their mineral composition is mainly represented by quartz as well as impurities of muscovite, hematite, magnetite, chlorite, shungite, zircon, rutile, pyrite with a total content of up to 3 %. The dump quartzite tailings contain particles less than 5 mm in size with a predominance of dust–like fractions (less than 0.16 mm). As to the grain composition, content of dust and clay particles, clay lumps and impurities tailings of the current output meets the requirements of Russian Standard no. 31424 (for the sand from sifting of crushing solid stone), belong to the class II, group of large sands; dump tailings belong to class I and the group of medium sands. Up to 30 % of the particles are plate– and needle–shaped. The features of changes in chemical composition, bulk density, content of dust–like, clay and organic impurities depending on the size of tailings fractions are considered. The possibility of using of tailings of quartzite enrichment as sand for construction works and fine fractions of tailings as molding material in foundry and granular loading in pressure and non–pressure filters for water purification is shown.

Keywords: quartz, tailings, composition, properties, use.

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1. Introduction

The quartzite of "Gora Karaul'naya" deposit is used in the production of dinas refractories for coke oven batteries and linings of glass furnaces by JSC "DINUR". In accordance with the adopted technological scheme of dinas production after crushing quartzite is

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subjected to enrichment with getting standard fraction more than 5 mm and fine fraction of the raw material (enrichment tailings of current output) are placed in slurry storage. Quartzite tailings of previous years in the amount of 0.6 million tons are stored in a dry dump. Sludge and dry tailings of enrichment have repeatedly been the object of study of the plant employees, the Eastern Institute of refractories and the Ural Federal University. The most complete studies were carried out in 1976, 1993, 1996 and 2016. The aim of this study was to determine the chemical–mineral and grain compositions, the quality of quartzite tailings of the current output (QTCO) and quartzite tailings from the dumps (QTD), the comparison of their properties with the requirements of regulatory documents for quartz construction, molding and filter sands.

2. Results and Discussion

The physical properties of the six samples of tailings of quartzite enrichment taken from the sludge pond and the dump are shown in Table 1. It was found that the humidity of QTCO is 5.6–10.3 % and of QTD – 3.9–6.6 %. Their grain composition is mainly represented by particles smaller than 5 mm with a predominance of dust–like fractions (less than 0.16 mm) in the QTD. QTCO have a fineness modulus of 2.6–3.2 and QTD – 2.0–2.6. The content of dust and clay particles in QTCO is from 3.0 to 6.2 % which is several times more than this index of QTD (1.1–1.9 %). Tailings contain plate– and needle–shaped particles in the amount of 24.3–29.3 %.

Chemical analysis of quartzite tailings samples showed that the QTCO contain less aluminum oxide on average by 2 times; iron oxide by 4.6 times and have practically no CaO in compared to QTD (see Table 2). In the tailings sulfur is mainly represented by sulfides and alkalis are in the range of 0.20–0.38 % by Na_2O.

The mineral composition of the tailings is represented mainly by quartz and muscovite impurities in an amount of up to 2 % (see Table 3). Clay lumps in tailings are absent. As secondary impurities tailings contain hematite, magnetite, chlorite, shungite, zircon, rutile, iron hydroxides and pyrite with a total content of up to 1 %. The mineral composition of QTCO and QTD is practically similar and is represented mainly by all minerals previously described in quartzites and host rocks of the deposit [1, 2].

Minerals diagnosis was performed using optical microscopy (microscope “Olympus BX41M–LED”, magnification up to X1000). The mineral composition of the tailings as well as the initial quartzites in large fractions is represented by quartz crystals with micro-inclusions of minerals of various chemical classes (silicates, oxides, aluminosilicates, rarely sulfides, hydroxides, etc.). A significant difference in the mineral composition and microstructure of particles (aggregate polycrystalline and polymineral grains) of crushed quartzite of dark and white color was established. Dark–colored grains contain pyrite, zircon, chlorite, hematite, muscovite, biotite, rutile and carbonaceous x-ray amorphous substance (such as shungite) giving them a dark color (see Figure 1). In light–colored grains pyrite and primary chlorite are absent and in place of pyrite crystals closed faceted pores fully repeating the cubic habitus of the original sulfide are formed (see Figure 2). Often these grains are painted in yellow brown color due to impurities of gel “limonite” ($Fe_2O_3{\cdot}nH_2O$).

Table 1: Physical properties of quartzite enrichment tailings of JSC “DINUR” (authors’ work).

The sam-ple num-ber	Loca-tion of samp-ling	Hu-midity [%]	Density [kg/m^3]		Content of particle [mass %] of size [mm]						Full resi-due on sieve no. 063 [%]	Fineness modulus	The content of dust and silt particles [%]	Presence of organic impurities
			True	Bulk	2.5-5.0	1.25-2.5	0.63-1.25	0.315-0.63	0.16-0.315	< 0.16				
1	Sludge pond	7.03	2640	1504	14.5	15.6	26.1	17.1	11.9	14.8	56.2	2.6	4.6	Solution dyed weaker than standard one
2		5.59	2735	1524	27.7	21.1	21.3	10.8	7.4	11.7	70.1	3.2	6.2	
3		10.29	2660	1580	22.5	19.3	21.2	12.2	9.8	15.0	63.0	2.9	3.0	
4	Dump	6.62	2649	1572	19.9	13.1	22.7	16.6	10.5	17.3	5.7	2.6	1.9	
5		3.93	2646	1501	21.6	13.7	16.9	10.5	9.5	28.1	52.2	2.4	1.1	
6		5.5	2645	1473	12.7	13.2	16.7	10.3	9.5	37.6	42.6	2.0	1.7	

Table 2: Chemical composition of tailings of quartzite enrichment (authors’ work).

The sample number accord-ing to Table 1	Mass losses of ignition [%]	Mass content [%]									
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3		Na_2O	K_2O	Other
							sulphate	sulfide			
1	0.13	97.52	1.08	0.35	0.02	0.09	0.03	0.48	0.30		0
2	0.26	97.50	0.60	0.42	0.01	0.12	0.05	0.70	0.27		0
3	0.06	97.05	0.73	0.39	0.02	0.80	0.11	0.64	0.12	0.13	0
4	0.29	95.43	1.27	1.40	0.27	0.12	0.03	0.75	0.22	0.21	0.01
5	0.34	94.62	1.45	1.93	0.30	0.14	0.04	0.67	0.24	0.23	0
6	0.56	93.20	2.27	2.03	0.62	0.14	0.03	0.67	0.14	0.24	0.05

Chlorite and dark mica (biotite) also undergo by chemical weathering but at a much lower rate with the formation of characteristic fractured, elongated voids. As a result of oxidation of shungite the color of the former dark grains of quartzite (local name “bruise”) was lightened. Due to weathering the total porosity increases by 5–15 times, the mechanical strength and hardness decreases drastically but the purity of quartzite improves (up to 99.3 % SiO_2). A Figure 3 shows typical veined forms of thin–crystalline individuals of hematite (white) and chlorite (dark) in quartz. The fine fraction of the dump tailings consists of fragments of larger quartz crystals with micro–inclusions and independent particles of secondary impurity minerals as well as dispersed sawdusts of hardware iron (see Figure 4).

As to the grain composition, content of dust and clay particles, clay lumps and impurities the QTCO meet the requirements of Russian Standard no. 31424 [3] for sand from sifting of crushing solid stone belong to the II class, to the group of large sands (see Table 4). QTD according to the grain composition (except to the content of fractions less than 0.16 mm, the content of dust and clay particles, clay lumps and impurities) meet the requirements of Standard mentioned above, belong to the I class and the group of medium sands.

The physical properties and chemical composition of the fractions of the tailings under investigation were determined. It was found that with a decrease in the size of the fractions the bulk density decreases, the content of dust–like and clay particles increases, especially significantly in fractions obtained by sieving of QTD. According to the content of dust and clay particles and organic impurities all fractions (from 0.16 to 5 mm) of the QTCO meet the requirements of Russian Standard no. 31424. At the same time the fractions of 2.5–5 and 1.25–2.5 mm of QTD meet the requirements of this standard for the content of dust and clay particles and organic impurities and other fractions (less than 1.25 mm) do not correspond to them in the number of dust and clay particles (more than 2.0 %). With decreasing of size fraction the mass losses of ignition, the content of oxides of aluminium, iron and alkalis increases, the silicon oxide is reduced, the sulfur dioxide varies slightly.

To the greatest extent sesquialteral oxides present in fractionated sand from QTD. The dust–like fractions of both tailings are characterized by a lower content of SiO_2 and a maximum amount of contaminants.

The properties were determined and the possibility of using of fine fractions of quartzitic sands (from the QTCO) in foundry as moulding material for the manufacture of foundry molds and cores was studied. It is established that the fraction studied (0.16–0.63 mm) by all indicators meets the requirements of Russian Standard no. 2138 for molding sands [4]. Grade of foundry sand from the tailings of quartzite enrichment of fraction 0.16–0.63 mm is $5K_4O_1 03$ i.e. quartz molding sand with a mass fraction of clay component of from 1.5 to 2.0 %, mass fraction of silica is not less than 92,0 %, a uniformity coefficient is of more than 80,0 % and an average grain size more than 0.28 %.

The properties were determined and the possibility of using of fractionated quartz sand (from the QTCO) as a granular filter material for cleaning tap water was studied. It

Table 3: Mineralogical composition of quartzite enrichment tailings fractions (authors' work).

Mineral, chemical formula	Contents [mass %] in the fraction [mm]					
	Sludge pond, sample no. 1			Dump, sample no. 6		
	2.5–5,0	0.63–2,5	< 0.16	2.5–5,0	0.63–2,5	< 0.16
Quartz, SiO_2	97.2–97.8	97.1–97.6	94.3–97.2	97.0–97.6	95.9–96.6	94.7–95.4
Muscovite, $K_2O·3Al_2O_3·6SiO_2·2H_2O$	1.3–1.5	1.5–1.7	1.5–1.8	1.2–1.4	1.4–1.6	1.5–2.0
Hematite + magnetite, (Fe_2O_3 + Fe_3O_4)	0.3–0.5	0.2–0.3	0.2–0.3	0.3–0.5	0.4–0.6	0.6–0.8
Zircon, $ZrO_2·SiO_2$	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10
Pyrite, FeS_2	0.01–0.02	≤0.01	<0.01	0.02–0.03	0.01–0.03	<0.01
Chloride (compound hydroaluminium of Mg, Fe, Mn, Ni and Cr)	0.1–0.3	0.3–0.4	0.4–0.5	0.2–0.3	0.3–0.6	0.6–0.7
Carbonaceous substance, C (shungite)	≈0.1	0.1–0.2	0.2–0.3	0.2–0.3	0.2–0.4	0.2–0.4
Rutile, TiO_2	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10	0.1–0.3	0.05–0.10
Clay (montmorillonite + kaolinite)	–	–	0.1–0.3	–	–	0.3–0.5
Hydroxides of iron (limonite, hydrogoethite etc.)	–	0.01–0.02	0.03–0.05	0.05–0.10	0.1–0.2	0.3–0.5
Metal iron, Fe	–	–	0.2–0.3	–	0.1–0.3	0.3–0.4
Amorphous silica SiO_2 (chalcedony, opal, flint)	–	–	–	–	–	–
Sulphates (gypsum, anhydrite)	–	–	–	–	–	–
Organic substance (humus)	–	–	<0.01	–	–	<0.01
Apatite, $Ca_5(PO_4)_3[OH, F_2]$	<0.01	–	<0.01	–	<0.01	<0.01
Other (sphene $CaO·TiO_2·SiO_2$, ilmenite $FeO·TiO_2$ and other)	0.01–0.02	0.01–0.02	0.01–0.02	0.02–0.03	0.01–0.02	0.02–0.04

was found that the studied fraction (0.63–2.5 mm) of quartzite sand can be used as a granular loading in pressure and non–pressure filters.

When filtering tap water through quartz sand turbidity, color, iron and aluminum content are reduced. However the content of dry residue and manganese, permanganate oxidability increased slightly and the content of silicon remains almost unchanged. The mechanical strength of the filter quartzite sand characterized by grinding and abrasion was determined. It is established that quartzite sand is not crushed and not worn in the process of mechanical action and meets the requirements of Russian Standard no. 51641 [5].

TABLE 4: The properties correspondence of quartzite enrichment tailings to the requirements of Russian Standard no. 31424 for the sand from sifting of crushing solid stone (authors' work).

Characteristic	Classes of sands from sifting of crushing solid stone		Numbers of samples					
	I	II	1	2	3	4	5	6
A sand group according to fineness modulus	From 1.5 to 3.5		Large	Extra large	Large		Medium	
Full residue on sieve no. 063, mass. %	From 10 to 75		Corresponds					
Content of grains larger than 10 mm, mass. %	Not more than 0.5	from 2 to 5	Corresponds					
Content of grains larger than 5 mm, mass. %	Not more than 5	from 12 to 15	Corresponds					
Content of grains less than 0.16 mm, mass. %	Not more than 5	from 10 to 15	Corresponds to class II			Does not correspond		
Content of dust and clay particles, mass %	Not more than 3	Not more than 10	Corresponds to class II			Corresponds to class I		
The content of clay lumps, mass %	Not more than 0.35	Not more than 3	Not found					
Amorphous SiO_2 content, mol/l	Not more than 50		Not found					
The content of sulfur, sulfides, except pyrite (marcasite, pyrrhotite, etc.) and sulfates (gypsum, anhydrite, etc.) by SO_3, mass. %	Not more than 1.0		Below normal index					
Pyrite content by SO_3, mass. %	Not more than 4.0		Significantly below normal index					
Mica content, mass. %	Not more than 2.0		Not found					
The content of halides (halite, sylvite, etc.) including water soluble chloride by chlorine ion, mass. %	Not more than 0.15		Not found					
Coal, mass. %	Not more than 1.0		Significantly below normal index					
Presence of organic impurities (qualitative analysis)	Not allowed		Corresponds					

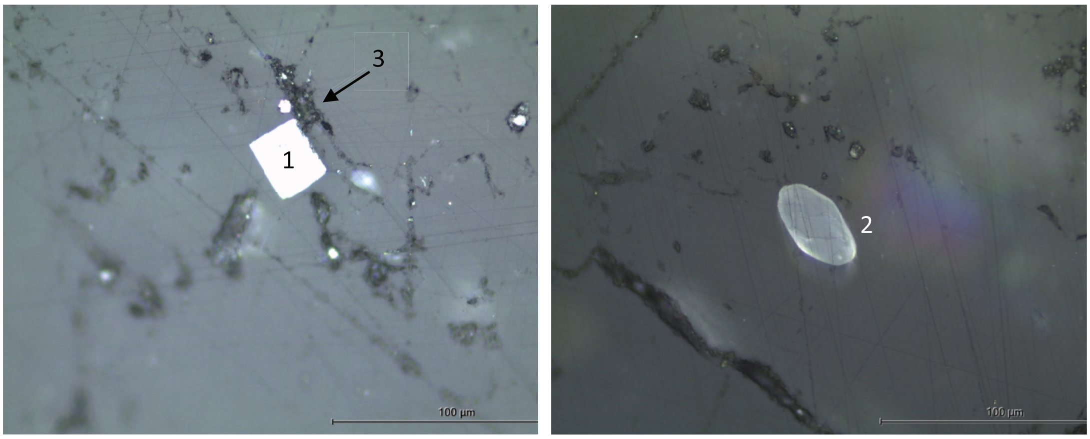

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Figure 1: Microstructure of dump dark gray quartzite of fraction 2.5–5.0 mm: 1 – pyrite; 2 – zircon; 3 – mica (muscovite) (authors' work).

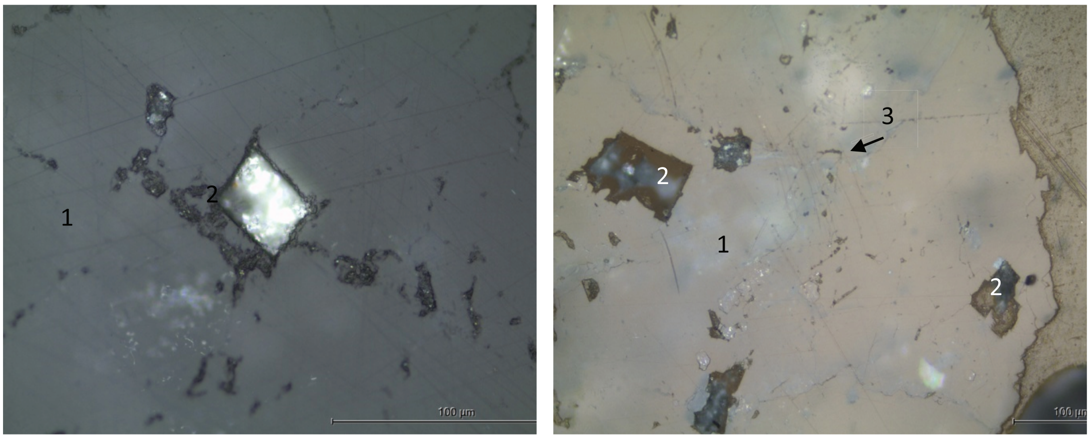

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Figure 2: Microstructure of light gray quartzite of QTCO of fraction 0.63–2.5 mm: 1 – quartz; 2 –void from leaching of oxidized pyrite; 3 – mica (authors' work).

3. Conclusion

Chemical, mineral and grain compositions, physical and mechanical properties and possible areas of use of quartzite enrichment tailings of "Gora Karaul'naya" deposit were identified. The prospects of their use as sand for construction works and after fractionation as molding sand and granular filter material are shown.

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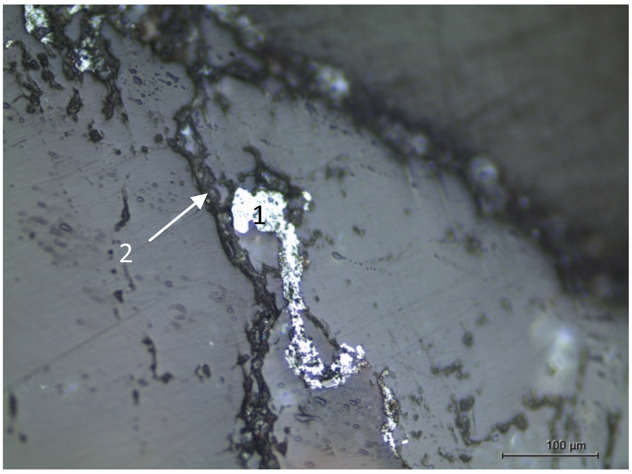

Figure 3: Microstructure of quartzite of current production (fraction 0.63–2.5 mm): 1 – hematite; 2 – chlorite (authors' work).

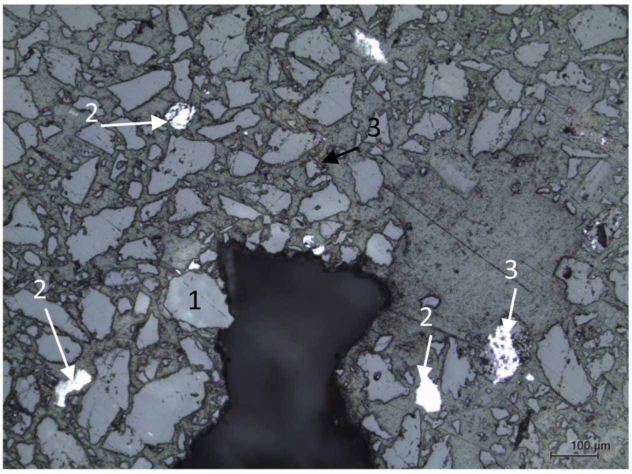

Figure 4: Microstructure of grains of dump quartzite (fraction < 0.63 mm): 1 – quartz; 2 – the metal iron; 3 – hematite+magnetite; 4 – zircon (authors' work).

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